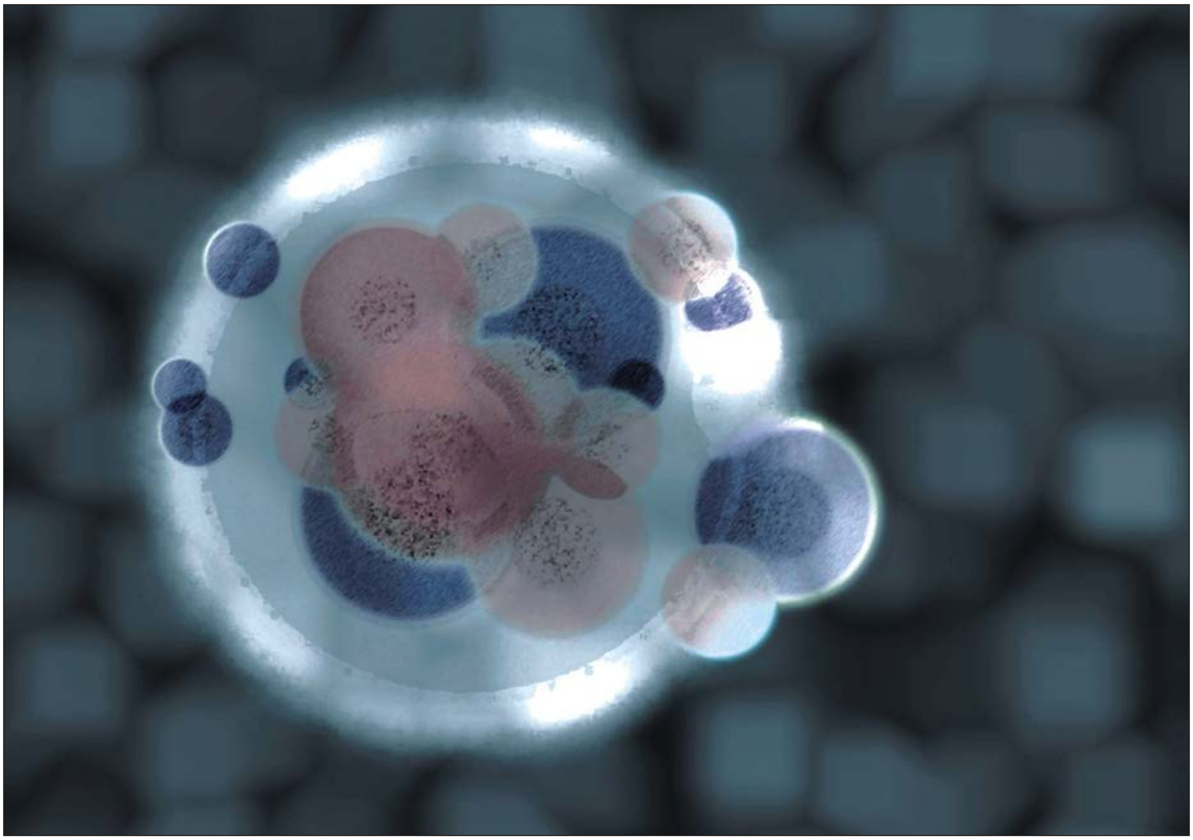

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Research Article
Improvement of Energy Efficiency in Waste Water Treatment Plant by Enhancing Performance of Anaerobic Digestion

[1]M.F. Abdul Hamid and [2]N.A. Ramli

Electrical Engineering Section, International College, Universiti Kuala Lumpur, Batu 8, Sg Pusu, Gombak, Selangor, Malaysia

Abstract
To achieve energy efficiency, energy management and optimization works across of the entire waste water treatment plant. Some equipment and processes, such as pumps and air blowers related to aeration tanks are particularly need more energy and afford opportunities for major savings. In this technical study, an analysis regarding improvement of energy efficiency in waste water treatment plant is done by enhancing performance of activated sludge feeding from primary clarified tank to anaerobic digestion. Appropriate optimal design process control and efficient operation of anaerobic digester involves employing proper feeding patterns, short sludge retention time, mixing and recycling and others. The ratio of primary and secondary sludge is taken as an influencing factor as well. The ticker the activated sludge from the primary clarified, the more badges is produced, as indicated by the correlation between gas production and chemical oxygen demand/biochemical oxygen demand mass loading. By increasing total suspended solids concentration of the sludge through thickening, the results showed the volume of gas generation is increasing around 15% of design. As a result, the sludge treatment process is configured to operate efficiently thus reducing the active power of the respective equipment at aeration tank.

Key words: Waste water treatment, energy efficiency, anaerobic digestion, biogas production

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Corresponding Author: M.F. Abdul Hamid, Electrical Engineering Section, International College, Universiti Kuala Lumpur, Batu 8, Sg Pusu, Gombak, Selangor, Malaysia

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Water is a very important element in our everyday life. We need clean water to drink, cook, wash, bath and others. Since, world population keep increasing year by year, then we need another source to make sure that we are not facing with shortage of water supply[1]. The treatment of waste water is one of the key aspects of protecting water resources. However, it is not easy to operate waste water treatment plant with minimal cost[2]. From Indah Water Konsortium's report, electricity cost was RM 152.50 mil in 2010 and the number is keep increasing from 2007. Electricity cost also is the highest contribution of total regional waste water treatment plant expenses, followed by parts and contractor cost, other operating expenses, salary related overhead and office rental and premises.

Electricity cost is expected to increase over the years as the no. of plot ratio and density of developments within regional waste water treatment plant is keep increasing more than allowable in urban area to connect to the existing sewer line. According to the energy expenses record available from 2003, until 2010, the data indicated that the energy consumption has started to hike since 2006. The quantum of the energy increased is formidable, double digits increase in percentage from 17.3% in 2006, which peak in 2008 of 26.5% increase in energy cost. Therefore, the improvement of energy efficiency is needed in order to reduce the electricity cost hence, decreasing the total of operational cost.

There are lots of successful examples showing the enormous potential of increasing energy efficiency[3]. A general example is the stress waste water treatment plant in Austria[4], which has reached 108% of energy recovery through increasing energy efficiency[5]. Generally, in order to achieve energy efficiency, energy management and optimization studies across entire waste water treatment system. Some equipment and processes such as pumps and aeration tanks are particularly used lots of energy but at the same time afford opportunities for major savings. In this study, improvement of energy efficiency is based on the 3 steps, which all of them related with enhancing performance of anaerobic digestion (ADs)[6].

Anaerobic digestion facility is a process that enables reduction of sludge volume, stabilization of sludge and improvement of safety and sanitation[7]. However, the operation and maintenance of anaerobic digestion facility is difficult because there are many parameters to be controlled, such as sludge characteristics, sludge volume and operation cycle. There are also many related equipment to be operated with the digestion facility. Furthermore, there are cases when abnormalities occur inside digester, it will take longer time to recover to its normal operation condition compared with sewage treatment facilities Therefore, in a sewage treatment plant, this facility requires attention the most.

Previous study done by Massachusetts Department of Environmental Protection demonstrated that many things can be done at the anaerobic digestion in order to 7 energy which 1 of them is by producing more biogas[8]. Since, this study emphasizes more on anaerobic digestion system.

MATERIALS AND METHODS

Reducing electricity consumption of regional waste water treatment plant can be carried out through improvement of both the hardware (mechanical equipment) and soft technology (process and operation)[9]. Through mechanical equipment and operation, there are many parameters that can be controlled such as, sludge characteristics, sludge volume and operation cycle and there are many related equipment to be operated with digestion facility. Some of these parameters are observed and their laboratory sample results will be taken to determine gas production volume. Three steps are performed in order to increase the concentration of the activated sludge from Primary Clarifier Tank (PCT), to reduce the volume of waste sludge from Secondary Sedimentation Tank (SST) to Thickened Sludge Holding Tank (TSHT) and finally to produce higher concentration at gravity thickener.

Step 1: Rationalize process design: From management of design book, the definition of rationalizing the design process is adopting a mental lens through, which one can see the relation of the parts to the whole in the process itself. In this 1st step, the energy efficiency is done by parts[10]. This objective is to improve the energy efficiency but at the same time, we must follow existing standards as the regional waste water treatment plant operate and maintain to produce absolute effluent quality that comply to standard B under the provisions of the Environmental Quality Act[11]. Standards have been established for the quality of effluent discharged from treatment plant to river. These absolute standards take the form of acceptable upper limits for various influent characteristics parameters defined by EQA[11].

Effluents from treatment plant are regularly sampled and tested in laboratories to ensure that we still meet the standards even after optimization has been applied.

The major indices that are measured consist of Biochemical Oxygen Demand (BOD), Suspended Solids (SS), Chemical Oxygen Demand (COD), oil and grease, ammoniacal nitrogen, nitrate nitrogen and total phosphorus. The actual results from sampling showed there are some improvement in performance of the effluent standards after optimization as shown in Table 1.

To rationalize process design, mass flow and balance are essential for in-depth understanding of a plant process design and performance of individual unit. The development of mass and balance for process selection is done by using Microsoft Excel as shown in Fig. 1.

In developing mass and balance for optimal process selection, there are a few processes that should be monitored and controlled. For starting, the solid concentration from PCT until anaerobic digester tank is measured and obtained from the calculation. Further efforts needed to improve the sampling of dewatering process and digested sludge storage tank. After PCT, the gravity thickener should produces the solid concentration up to approximately 2.3% based on sampling observation. Subsequently, Thickened Sludge Holding Tank (TSHT) should be gradually increase the volume of PCT with sludge and reducing the Secondary Clarifier Tank (SCT) accordingly. By increasing the wasting sludge from PCT, the organic loading to aeration tank will be reduced proportionally and resulting less sludge wasting in SCT.

After developing mass and balance for optimal process selection, the alteration process concentrates on the sludge treatment facilities since reduction of sludge cake volume sewage is important to minimize impacts to the environment and reducing the operation cost. Sludge produced from treatment process is usually in liquid form, which typically contains 0.25-4.0% of solids, depending on the type of treatment process. It also contains grease, fats, organic and inorganic chemicals. High concentrations of certain components will determine the type of sludge treatment process to be used. Sludge shall be thickened, stabilized, conditioned and dewatered before it is finally disposed, following the requirement stipulated by Department of Environment. The dried sludge must attain a minimum of 20% dry solid content before off-site disposal.

Additional sampling and testing, mainly on the solid content are performed for verification purposes. Reliable key parameters and data are adopted in verification of the value reported for example Sludge Retention Time (SRT) of the

Table 1: Characteristics of influent and effluent standards for the main parameters

Items	Influent sewage (mg L^{-1})	Effluent standards (mg L^{-1})
BOD	120-180	2-2.5
Suspended Solids (SS)	180-220	2-4
Total Nitrogen (TN)	28-33	5-12

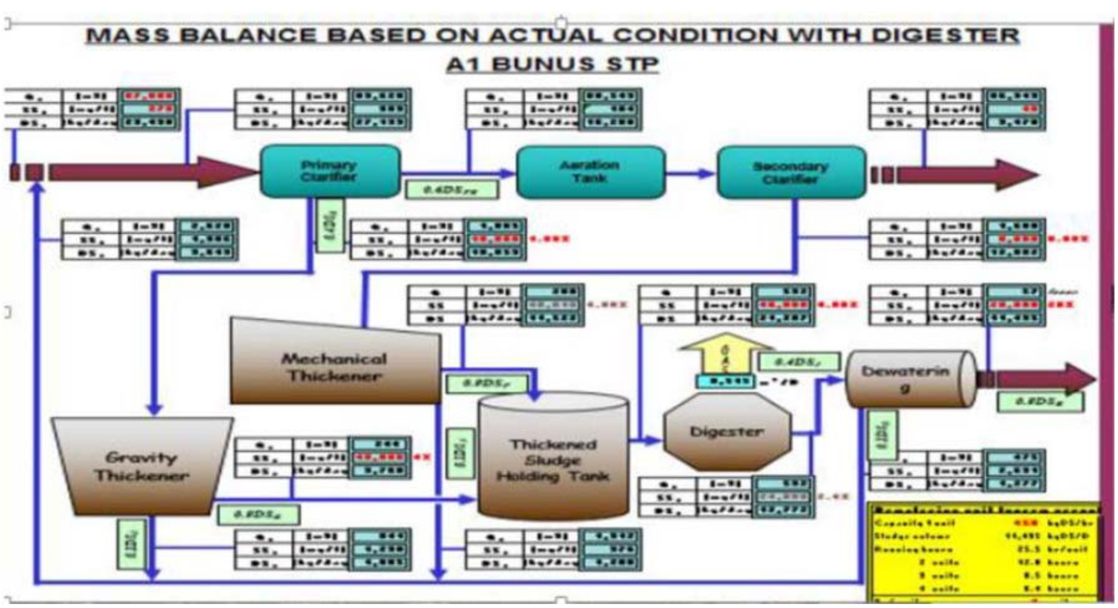

Fig. 1: Developing mass and balance for optimal process selection

Table 2: Reduction and saving of sludge cake production volume

	Production of sludge cake	
Sludge cake yard	Before	Target
Reduction of volume (t day^{-1})	57	41
Saving sludge disposal (%)	39	
Transportation (RM/annual)	438,000	

activated sludge process used to check flow and solid concentrations of waste activated sludge, volatile suspended solid destruction, bio gas production and composition of anaerobic digesters used to check solids concentrations entering and existing the digester, dewatering cake composition used to check Total Suspended Solids (TSS) after digesters and flow of dewatering concentrate). Table 2 shows the production of sludge cake before and our target after developing mass and balance for process selection.

A part of the above process, solids treatment process plays an important role too as it is closely related with the electricity recovery in regional waste water treatment plant. The solid process (or solid stream) has a significant impact on the cost of building and operating the regional waste water treatment plant, accounting for upto 50% of regional waste water treatment plant's capital cost. Due to regulation and public pressure, an increasing number of technology categories are being considered to optimize the design and sustainability of the solids treatment system, such as solids minimization, greenhouse gas emission and electricity energy recovery. In many cases, pre-treatment is conducted only for secondary sludge as the biodegradation of primary sludge is much higher than that of secondary sludge. The selective sludge pre-treatment will be able to reduce size of the pre-treatment facilities and reduce the cost of operation. As such, it probably also increases the final dry solid concentration.

Step 2: Enhancing Preliminary Treatment (EPT): The design and operation of the PCT and activated sludge process has a direct impact on the amount of sludge sent to anaerobic digesters for better enhancement of biogas. The amount of primary sludge depends on the removal efficiency of the primary clarifiers, which varies from 40-60% for TSS removal. Enhanced precipitation is employed in EPT aiming to increase amount of primary solid from PCT and sending it to anaerobic digesters to increase biogas production, also to reduce oxygen demand and biomass produced in the secondary biological process (Aeration tank).

Step 3: Enhancing performance of anaerobic digestions (Ads): Similar to EPT process, the primary goal of this type of fast activated sludge process is a diversion of more organics from the liquid stream to the solid stream to increase energy recovery. This type of activated sludge process has the features of short Sludge Retention Time (SRT) and Hydraulics Retention Time (HRT). The ADs involves bacterial decomposition of the bio-solid organic constituents in the absence of oxygen. Besides solids, the products of ADs are including water and biogas composed of methane, carbon dioxide, hydrogen sulphide and other minor gaseous with methane as the major component.

Appropriate optimal design process control and efficient operation of anaerobic digester involves employing proper feeding patterns, SRT, mixing and recycling. The ratio of primary and secondary sludge is an influencing factor as well. Also, the ticker the sludge from the primary clarifier and secondary clarifier, the more biogas is produced, as indicated by the correlation between gas production and COD/BOD mass loading. Increasing TSS concentration of the sludge through thickening may be beneficial for more biogas production. Hence, the sludge treatment process will be configured to operate efficiently, thus reducing the active power of the respective equipment at biomass process (Aeration tank).

RESULTS AND DISCUSSION

After implement these three steps which we called as Continuous Improvement Project (CIP), we obtained a few results to show the increasing of biogas which can help to reduce active power for equipment in aeration tank. First, by increasing TSS concentration of the sludge through thickening, the volume of gas generation has been increased from 876.55 m^3 day^{-1} (which around 9.7% of design) to 1307.29 m^3 day^{-1} (14.5% of design) as shown in Table 3 and Fig. 2. The results that we obtained are also show improvements in terms of pH, which is closer to the design and the hydraulic retention time is shorter than before[12].

First stage of the CIP (2013) project has achieved the target to increase the biogas generation from average 876.55-1307.29 m^3 day^{-1} based on Table 4. Second stage of the CIP (2014) project has achieved the target to maintain and optimum of biogas generation. To date, biogas generation has maintain in an average of 1850.07 m^3 day^{-1}.

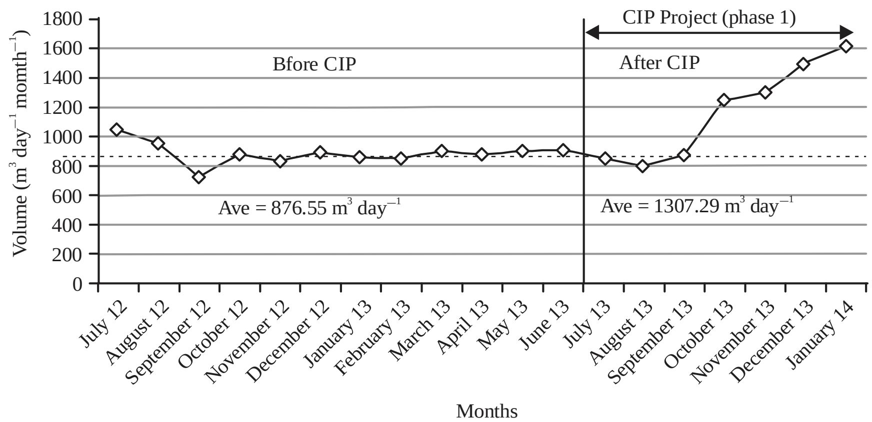

Fig. 2: Enhancing gas generation under initiative CIP

Table 3: Digester performance before and after continuous improvement project (CIP) phase 1

Items	Before CIP (2013)	After CIP (phase 1-2014)	Design
Bio-gas generation (m^3 day^{-1})	876.55	1307.29	9000
Feed sludge volume (m^3 day^{-1})	353.69	481.31	600
Feed sludge density (%)	0.6	0.94	4
Hydraulic retention time (day)	31.88	28.59	30
Temperature (°C)	31	30	31
pH	6.54	6.77	6.7-7
Digester operation (U)	3	3	4

Table 4: Digester performance and improvement of volume biogas generation

Items	Before CIP	After CIP (phase 1)	Ultimate CIP (phase 2)
Bio-gas generation (m^3 day^{-1})	876.55	1307.29	1850.07
Feed sludge volume (m^3 day^{-1})	353.69	481.31	612.24
Feed sludge density (%)	0.6	0.94	1.30
Hydraulic retention time (day)	31.88	28.59	30.33
Temperature (°C)	31	30	31
pH	6.54	6.77	6.75
Digester operation (U)	3	3	4
Sludge cake generation (t day^{-1})	40-60	30-40	30-40

CONCLUSION

To conclude, the implementation of these three steps explained in research methodology is a smart way for energy efficiency. This is study, from the results that we obtained show the more biogas is being produced, the more efficient sludge treatment process is configure to operate. Thus, reducing the active power of the respective major equipment at aeration tank. There are some of other steps that can be implemented in order to achieve energy efficiency, such as optimize pipe design, prediction of energy consumption and implementation of hybrid system which can be done in our future study.

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REFERENCES

1. DSM., 2011. Population distribution and basic demographic characteristics report 2010. Department of Statistics Malaysia (DSM), Sustainability Report 2010, July 2011, pp: 1-63.
2. Moreira, D.F. and H.M. Ramos, 2013. Energy cost optimization in a water supply system case study. J. Energy, Vol. 2013. 10.1155/2013/620698
3. Shi, C.Y., 2011. Mass Flow and Energy Efficiency of Municipal Waste Water Treatment Plants. IWA Publishing, USA., ISBN: 9781843393825, Pages: 132.
4. Drinan, J.E. and F. Spellman, 2012. Water and Wastewater Treatment: A Guide for the Nonengineering Professional. 2nd Edn., CRC Press, USA., ISBN: 9781439854013, Pages: 300.
5. Wett, B., 2007. Development and implementation of a robust deammonification process. Water Sci. Technol., 56: 81-88.
6. Nitivattananon, V., E.C. Sadowski and R.G. Quimpo, 1996. Optimization of water supply system operation. J. Water Resour. Plann. Manage., 122: 374-384.
7. Descoins, N., S. Deleris, R. Lestienne, E. Trouve and F. Marechal, 2012. Energy efficiency in waste water treatments plants: Optimization of activated sludge process coupled with anaerobic digestion. Energy, 41: 153-164.
8. Wong, S.C., 2011. Tapping the energy potential of municipal wastewater treatment: anaerobic digestion and combined heat and power in Massachusetts. Department of Environmental Protection, Massachusetts.

9. MWA., 2012. Malaysia water industry guide 2012. Malaysian Water Association (MWA), Malaysia, pp: 1-55.
10. Williams, S.L., 1994. Rationalizing the Design Process. In: Management of Design: Engineering and Management Perspective, Dasu, S. and C. Eastman (Eds.). Springer, Netherlands, pp: 233-253.
11. EQA., 2009. Environmental quality (industrial effluent) regulations 2009. Environmental Quality Act, December 10, 2009, pp: 1-50.
12. Singh, J. and H. Singh, 2013. Continuous improvement strategies: An overview. IUP J. Operat. Manage., 12: 32-57.